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Study of Vacuum Braking System

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ABSTRACT-

Vacuum brakes are first used in place of the air brake in railway locomotives. This braking system uses a vacuum pump for creating vacuum in the brake pipe. The integral construction of the brake cylinder uses this vacuum reservoir for the application of brakes. Nowadays most of the light vehicles are fitted with vacuum-assisted hydraulic braking system where vacuum is created from the engine which reduces the driver effort on foot pedal.When the vacuum-powered brake *booster in a passenger vehicle becomes disabled, the* brake *force gain of the* system *is reduced significantly, and the brake pedal force required locking the tires increases beyond the ability of some adults.*

Keywords – Vacuum braking system, vacuum pump and train pipe, vacuum cylinder

I. INTRODUCTION

Brakes are mechanical devices which increases the frictional resistance that retards the turning motion of the vehicle wheels. In vacuum assisted hydraulic brake system, a constant vacuum is maintained in the brake booster by the engine. When the brake pedal is depressed, a poppet valve opens and air pushes into the pressure chamber on the driver's side of the booster.

Bartlett [1] worked on the vacuum powered brake booster in a passenger vehicle becomes disabled, the brake force gain of the system is reduced significantly, and the brake pedal force required to lock the tires increases beyond the ability of some adults. In such cases, the maximum braking deceleration achieved by those individuals will be something less than the upper boundary as defined by available traction.

Shaffer and Alexander, determine whether the performance-based brake testing technologies can improve the safety of the highways and roadways through more effective or efficient inspections of brakes of the road commercial vehicles. However, the performance-based technologies were able to detect a number of brake defects that were not found during visual inspection. [2]

Saeed Mohammadi and Asghar Nasr, found that for the heavy haul trains. Coupled often, there is no alternative to the air brake system. In these trains, the cars at the end of the train brake a few seconds later than those at the front. The time delay between the braking of the adjacent cars depends very much on the transmission speed of the pressure wave (brake signal) in the main brake pipe, which is about 10-25% less than the speed of sound in free air. The later braking of the cars at the rear of the trains means that the rear cars run into the front cars, producing large compression forces on the buffers and couplings. These compression forces are longitudinal in nature and are considered to be responsible for large amount of expenses regarding rolling stock and track sub- and super-structures repairs, as well as the deterioration of safety operation of the trains.[3]

Chinmaya and Rahul suggested a unique of decoupling feature in friction disk brake mechanisms, derived through kinematic analysis, enable modularized design of an Anti-lock Braking System (ABS) into a sliding mode system that specifies reference brake torque and a tracking brake actuator controller. Modelling of the brake actuation, vehicle dynamics, and control design are described for a scaled vehicle system. The overall control scheme is evaluated by hardware-in-the loop testing of the electromechanical brake system.

Bharath et al deals with nonlinear lumped multicapacity models with train pipe capacity and brake cylinder capacity lumped separately to predict pressure rise in the pneumatic.[4]

II. PRINCIPLE OF OPERATION

A vacuum braking system comprises a method of evacuating the air from a pipe running the length of the train, the ‘train pipe’ (either using a steam locomotive’s “ejector” or an electrically driven vacuum pump) to create a vacuum, and a method of destroying this vacuum. The brake system is arranged so that when the vacuum is created the brakes are pulled off; but when it is destroyed the brakes are applied. This has the advantage of being fail-safe, i.e. in the unlikely event that a pipe was to break (for example, if a passenger coach became detached from the loco) the air introduced to the coaches brake system would destroy the vacuum applying the coach’s brake automatically and bringing the coach to a controlled stop. This picture may help(fig.1) you understand how vacuum braking works, but please remember that in the "real world" the components will be properly engineered. For example the "small rubber flap" described below would more likely be a nicely built one-way valve rather than a bit of rubber covering a hole In the drawing, part of the carriage wheel is shown at the bottom left. A brake block (colored brown) is connected by the lever arm to the brake cylinder piston and piston rod (bright green). A weak spring is used to pull the brake block away from the wheel, which also moves the piston to the left hand side of the vacuum brake cylinder (colored blue). Inside the cylinder is a rubber diaphragm (pink) that seals the piston to the cylinder, dividing the cylinder into two halves. The final component (that is rather hard to see) is a small rubber flap (colored red) that is on the left hand side of the piston. This small rubber flap covers a small hole in the piston. The pipe (A) from the cylinder is Connected to the locos ejector (or vacuum pump), via the "train pipe" while the pipe (B) goes to a large tank that acts as a vacuum reservoir. If you start sucking the air out of the system via pipe (A) the small rubber flap will be sucked away from the piston and you will then also suck the air out of the vacuum reservoir. This will take quite a lot of sucking as there is a lot of air to remove. By convention the amount of vacuum you create is measured in Inches of Mercury, and most miniature railway vacuum braking systems are built so that 15 inches of vacuum will pull the brakes off. So for safety you will keep sucking until you have achieved about 20 inches of vacuum in the train pipe, both sides of the brake cylinder, and in the vacuum reservoir. When you stop sucking the "pressure" of the vacuum will be the same on both sides of the piston, so the weak spring will hold the brake in the off position and the small rubber flap will "spring" back to cover the hole in the piston. If you now let air into the train pipe the pressure of the air will be greater than he pressure of the vacuum (normal air pressure corresponds to zero inches of Mercury) so the small rubber flap will be pushed firmly against the piston to seal the hole and the piston will be pushed by the air pressure towards the right of the cylinder. This will apply the carriage brake to the wheel.

When you want to release the brake again you will only need to suck the air out from the train pipe and the left hand side of the piston until you reach the same level of vacuum as remains in the vacuum cylinder connected to pipe (B), at which point the weak spring will pull the piston back to the left and release the brakes. You can see that if the carriage becomes detached from the loco (or other carriages) the air will get in via pipe (A) and automatically apply the brakes on the detached carriage, and similarly the brakes will also be applied to all the remaining carriages attached to the loco. The brake system is "fail-safe". The only remaining problem is that if you want to remove a carriage from the train its brakes would be stuck on and you could not move the carriage. To overcome this, the vacuum reservoir will have a plug (vacuum relief valve) fitted that can be removed to destroy the vacuum in the reservoir and thus via pipe (B) on the right hand side of the piston. With the pressure on both sides of the piston being equal again (at normal air pressure) the weak spring can once again release the brakes.[5]

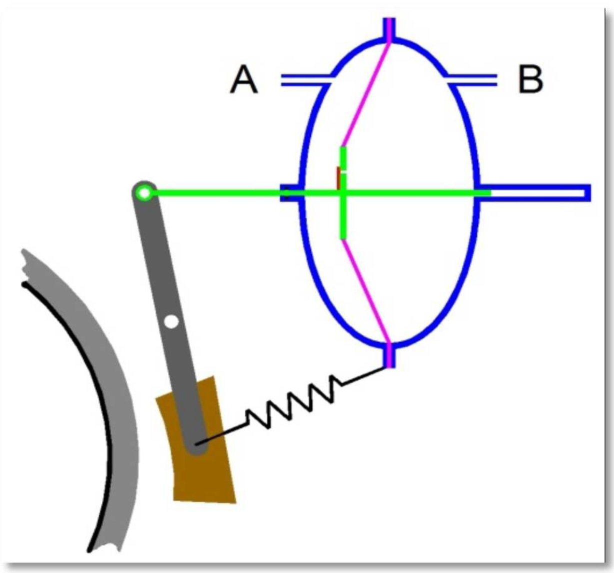


Fig.(1) SKETCH OF A VACUUM BRAKE SYSTEM

III. CONSTRUCTION OF VACCUM BRAKING SYSTEM

Vacuum braking system as shown in fig .(2) consists of brake cylinder, compressor, vacuum reservoir, direction control valve, flow control valve, brake hoses, brake linkages, drum brake and foot brake pedal.

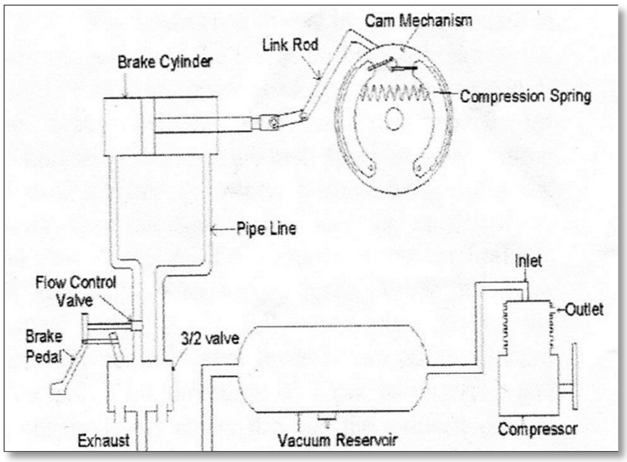


Fig (2) SKETCH OF LINE DAIGRAM OF THE VACUUM BRAKING SYSTEM

1. **Rubber hose pipe and siphon pipe.**

a) Renew the hose pipe and siphon pipes if they had cracked or lost the bond between the various layers/ components.

b) Reusable hose/ siphon pipes should be tested for vacuum retention. For this test, the hose should be connected by means of a cylindrical nozzle of size corresponding to the vacuum/ siphon hose bore to a chamber of **1640 cu. cm**. volume and the free end of hose closed with a cylindrical plug. **510 mm** Hg of vacuum should be created in the chamber and hose system. On isolation from the source of vacuum, the drop of vacuum should not be more than **75 mm Hg** in one hour on the chamber gauge. The pipe should not be clipped or otherwise bound to the chamber nozzle or plug for this test. The hose should also be bent around a mandrel of **228 mm** diameter till the ends of the hose are parallel. This should not result in any displacement or distortion of wire.

c) Cracks, porosity, tears, etc., of the hose should be detected by giving it a stretch test. For this purpose, hose pipe should be secured to a special jig and should be stretched to **20% over** its original length and released 100 times. Thereafter, in the stretched position, its surface should be examined to detect the defects, if any. Cracked, torn, porous, or collapsed hose pipes or hose pipes with coiled wire loose or missing, or length reduced below **50 cms**. Should be rejected.

d) Serviceable hose pipe should be secured on swan neck (after applying rubber solution on swan neck) with clip and tighten with spanner.

e) Renew the corroded or damaged hose pipe clips.Broken, damaged, or distorted cages should be replaced with modified cages to drg.No.VB 409/M. Universal coupling should be examined for broken, cracked and distorted lugs and renewed on condition basis. Rubber solution should be applied on the mating

2. Train pipe-

Check the train pipe with compressed air of 2 kg/cm2 for leakage specially at threaded joints, bends and portions where clamps are fitted, tee joints, swan neck, etc. with one end dummy. Check and replace corroded, dented, bent more than **10 mm**, or thin walled portions of the train pipes. Spiked hammer should be used to check thin wall, corrosion, etc. While renewing the pipe, it should be ensured that bending do not decrease the cross sectional area of pipe passage at the bends. New brake pipe should be given a coat of anti-corrosive paint before fitting. Renew the damaged/ missing brackets or clamps used for clamping the train pipe. All the pipe threads must be cleaned and applied with white lead before couplings are fitted. Clean the grooves on swan neck. After attending to all the repairs, test the train pipe for sound joints and bends with compressed air at **2 kg/cm2** pressure. There should not be any leakage of air over the entire length of the train pipe. After repairs and testing, the train pipe should be given a coat of anticorrosive paint.

3. Vacuum Reservoir Straps-

Vacuum reservoir straps should be examined for slackness, corrosion and thinning, and damaged or worn out threads at their ends. and entire straps or threaded ends, as required, should be replaced. If the securing holes in the under frame are worn more than **3 mm**, build up by welding and redrill the holes. The reservoir straps should be double secured with spring washer and check nuts. After all repairs, the reservoir straps should be given a coat of anticorrosive paint. FRP tissue should be placed in between reservoir and safety straps. APD should be done.

4. Vacuum cylinder trunnion bracket

Where bushes are provided in the brackets, they should be renewed and a light coat of graphite grease applied before fitting a cylinder. Trunnions of the cylinder must neither be too loose nor too tight in their brackets. Lateral clearances on the trunnions (on each side) should not exceed **3 mm**. It should be adjusted by renewing the bushes. If there are no bushes, the trunnions should be bored and bushes of correct size fitted to get the required clearance.

5. Alarm chain apparatus

During POH, alarm chain apparatus should be opened, cleaned and overhauled. The chain must be of the prescribed specification and each link must be physically examined for crack/ wear/ elongation. Proper fitment/ anchoring of all the components should be checked and ensured to avoid their failure/ non-operation/ mal-functioning during service. The clappet valve should be removed from the coach for overhauling. Replace the rubber washer. The clappet valve cover should be checked and repaired or replaced as necessary. The clappet valve operating rods, levers, indicating discs and other moving parts should be cleaned and checked and straightened if bent, or replaced if broken or deficient. The pins if worn should be renewed, if not they should be cleaned before reuse. The vertical pipe connecting the clappet valve with train pipe should be examined to ensure that it is neither leaking nor blocked. The air passage in the vertical pipe should be blown clear with compressed air and the pipe threads should be checked before the assembly is connected to train pipe. All moving parts including spring should be greased and checked for proper movement. The clappet operating chain and the pipe through which the chain passes should be dismantled, examined and renewed with standard chain or **6 mm** wire. If in normal position of the clappet valve, the chain hangs loose in any of the compartment openings, its length should be adjusted by cutting it out to the extent necessary. Wooden handles provided in the compartment openings for pulling the chain should also be checked and replaced where found broken or cracked. After the clapped valve assembly is overhauled and refitted, its chains, etc., are checked and replaced, the alarm chain apparatus should be tested at the outgoing pit for its operation in accordance with the following procedure.

6. Vacuum reservoir

The vacuum reservoir should be examined for corrosion, damages, distortion, cracks, etc. If the extent of corrosion, etc., is only about **5%** of total area, it should be cut off and replaced with another plate by welding. Otherwise the whole barrel should be replaced. Open the drain plug and blow compressed air into the reservoir to remove dusts, dirt and water particles, accumulated inside the reservoir. After thorough cleaning, refit the drain plug smeared with small quantity of graphite grease on the threads and tighten it firmly. Clean the pipe threads with a brass wire brush in both the dish ends to fit the siphon nipples. Replace the missing or damaged siphon in the dish ends of the reservoir. After attending the defects and before painting the reservoir, a pneumatic pressure of **2.0 kg/cm2** by gauge should be applied in it for the purpose of ensuring sound fabrication and finish. With the pressure applied, the welded seams all over the body should be thoroughly checked for leakage with soap and water solution. Vacuum reservoir should be tested for vacuum retaining capacity with **510 mm** of vacuum throughout the assembly. It should not, on isolation from the source of vacuum, record a drop of more than **13 mm in 30 minutes** on test gauge. After all repairs and tests, the reservoir should be given a coat of anticorrosive paint and FRP tissue pasted at the areas where suspension straps are located

7. Vacuum gauge

Vacuum gauge which is permanently fitted in guard's van should be removed and calibrated with master gauge before refitting. If defective, it should be repaired and again calibrated with master gauge and refitted. The vacuum gauge guard must be invariably provided to protect the gauge from damage or theft.

8. Vacuum brake cylinder

Strip the vacuum cylinder completely. Thoroughly clean and dry the components and check for defects like cracks, damages and wear.

9. Piston rod

Dismantle threads of the piston rod are damaged, the rod should be the piston rod from the piston. Renew the bent, damaged, dented, worn, corroded, or pitted piston rods. If the replaced.

10. Piston

The cracked piston should be replaced. The piston skirt serrations should be cleaned free of dust, rust and sediments. Visually check the piston for worn or cracks. Replace the piston if found damaged beyond salvage. Measure the outside diameter with micrometer of range 575-600 mm & record the dimensions. While assembling the Piston and Vacuum cylinder the diametrical difference between the two should be **20.3 mm**. The blind holes for the piston rod cover bolts should be tapped and eased.

11. Barrel (Cylinder body)

Cracked barrel including the one with cracked trunnions should be replaced. Lugs cracked or broken should be replaced with new lugs by welding and grinding. The barrel should be replaced if the number of original lugs (ie., those which have not been repaired at all) goes down below **50%.** Thoroughly clean the serrations and check for wear. Measure the inside diameter with micrometer of range 600-625 mm. Replace the barrel if serrations are found worn or damaged. Dry the barrel with hot air after wiping out all the traces of water particles. Clean the release valve seat and the holes for proper seating and free passage of air respectively. After attending to the defects and cleaning, inside of the barrel should be painted with one coat of anti-corrosive paint except the serrated surface, which should be left unpainted.

12. Joint rings

Every time a vacuum cylinder is opened, the joint ring should invariably be replaced. After fitting the joint ring in the correct position between flange of cylinder and cover, it can be retained in the correct alignment while fitting the cylinder cover to the cylinder by suitably designed clips.

13. Rolling ring

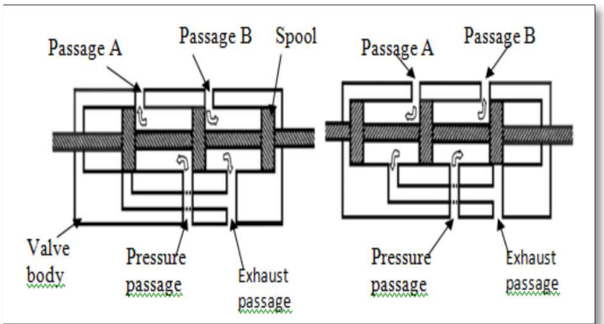
Twisted, cut, worn out or perished rolling rings should be replaced. While fitting a rolling ring on a piston surface, it should be ensured that it is of the correct size, i.e. diameter is either **13.1mm** or **13.5 mm** depending upon the wear on the serrated surfaces of the piston and the cylinder and, that the ring does not get twisted. The seam line of the rolling ring should be even and horizontal, when the ring is in its piston groove. In order to test the ring for twist, it should be hung on a stretched finger and examined. A good ring should hang straight and should not make a figure of 8 and show a twist. The rolling ring should also be stretched by hand and examined. If any cracks appear, it should be considered as perished and replaced. New rolling rings should be tested for compression and stretching. A 50-mm long test piece cut from the ring should be compressed to half of its sectional diameter and kept in the compressed condition for 3 hours. On release, if its diameter does not come back within **2%** of its original diameter within an hour, it should be rejected as defective. Similarly, the ring should be stretched to **300%** of its original length and kept in the stretched condition for 3 hours. If on release, the ring does not come back to within **5%** of its original length within an hour, it should be rejected as defective.

14. Release valve

Open the release valve and renew all the rubber items like diaphragm, seating washer, etc., invariably during Overhaul. Dry the release valve after wiping out all the traces of water. Check the release valve operating lever and renew if found cracked. The release valve studs should be cleaned and replaced if found damaged or worn. While assembling the valve, nuts should be smeared with graphite grease. It should also be ensured that all the sharp edges on the seat of the spindle washer are rounded off. After assembly, the release valve should be tested as given below:[6]

IV. DIRECTION CONTROL VALVE

The direction control valve is as shown in fig .3 (a) and (b) are used in this works to change the direction of air flow to and from the cylinder. The moving parts in the directional control valve will connect and disconnect internal flow passages within the valve body. This action results in control of airflow direction. The typical directional control valve consists of a valve body with four internal flow passages within the valve body and a sliding spool. Shifting the spool alternately connects a cylinder port to supply pressure or exhaust port. With the spool in the where the supply pressure is connected to passage A and passage B connected to the exhaust passage, the cylinder will extend. Then with the spool in the other extreme position, Supply pressure is connected to the exhaust port, now the cylinder retracts. With a directional control valve in a circuit, the cylinder piston rod can be extended or retracted and work will be performed. The working of direction control valve is shown in fig .2 (a) and (b).



(a) (b)

Fig (3) Working of direction control valve

Flow control valve

A flow control valve is as shown in fig.4 consist of a disc which opens and closes the two way connection between the 3/2 valve and brake cylinder. Operation is similar to that of a butterfly valve, which allows for quick shut off. The disc is positioned in the Y-shaped pipe, passing through the disc is a rod connected to an actuator on the outside of the valve. The need of flow control valve is for partial braking. When the valve is closed, the disc is turned so that it completely blocks off the passageway between the atmospheric path and brake cylinder.

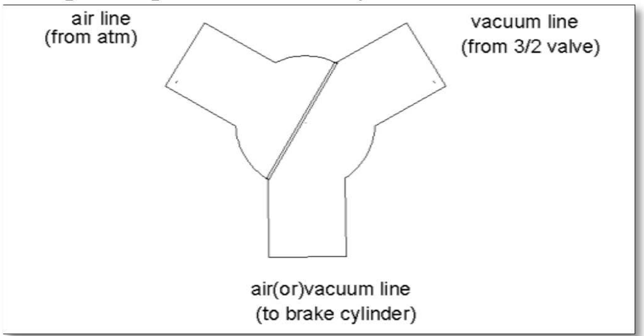


Fig (4) FLOW CONTROL VALVE

Drum brake

Drum brake system may be of either design in practice, but the twin leading design is more effective. This design uses two actuating cylinders arranged in a manner, so that both shoes will utilize the self-applying characteristic when the vehicle is moving forward. The brake shoes pivot at opposite points to each other. This gives the maximum possible braking when moving forward, but is not so effective when the vehicle is in reverse mode. The wheel cylinder and retractor spring of the drum brake is removed and suitable compression spring is fixed. The spring is placed in between the two cups so that it seats properly. The modified drum brake assembly is shown in fig.8. Flat shaped cam is made up of hard steel material is linked to the rectangular shaped plate made up of steel sheet are attached with the top ends of brake shoes. The other face of the cam is joined with L shaped link rod which is mounted with the piston rod end. The principle of vacuum brake is based on the pressure difference created in the actuator i.e. the brake released with a full vacuum and the brake applied with vacuum and spring force. The term “vacuum” is used to describe the region of pressure below one atmosphere of pressure, also referred to as negative pressure. The pressure in the atmospheric is defined as 0.1 N/mm2 and reducing atmospheric pressure to zero pressure creates a near perfect vacuum which is measured as 735 mm of mercury.

The brakes are always in released condition with vacuum until the driver pushes the brake pedal. In this condition, position of piston is in cap end of the brake cylinder and cam is twisted for compressing the spring which provides free rotation of drum. When the driver pushes the brake pedal slowly then the flow control valve opens slightly to the atmosphere. Loss of vacuum causes the brake to be applied due to spring force. When the flow control valve opens fully then alternatively the direction control valve lever is moved to forward direction. The direction of flow is changed and atmospheric air enters through the exhaust port of direction control valve to piston cap end. Due to pressure difference the piston moves backward with vacuum and spring force. The movement of link rod attached with piston rod releases the cam to normal position which makes internal resistances for the brake shoes against drum. This applies the brake.Fig.5 shows the brake is applied condition.

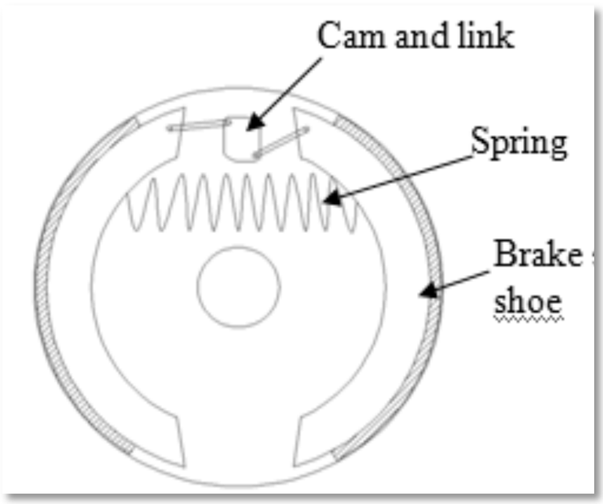


Fig (5) Cam and link mechanism after during brake

When driver releases the brake pedal, the valve lever comes back to initial position. The direction of flow is again changed and atmospheric air enters through the exhaust port of direction control valve to piston rod end. Due to the pressure difference, the piston moves forward with vacuum. The movement of link rod attached with piston rod twists the cam and compresses the spring to provide enough clearances between brake shoes and the drum. This releases the braking action. Fig.6 shows the brake in released condition.[7]

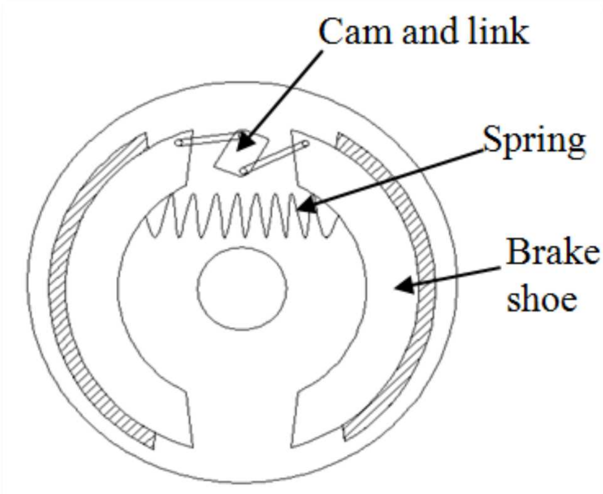


Fig (6) Cam and link mechanism the release brake

V. CONCLUSION

The design and fabrication of a braking system is a difficult and great task. The application of brakes using vacuum in automobiles was a difficult in the initial stages of the work. But it has been successfully proved that such brake application is possible with fail-safe condition. By implementing this idea on a heavy vehicle, it is better to replace the manually operated direction control valve with solenoid operated direction control valve to reduce driver effort and also it will also work like a brake pedal switch. The main advantages offered by the vacuum braking system are:

- This system provides fail-safe condition.
- Compressed air can be produced.
- Less noise.

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